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Measuring Travel Behavior of Low-Income Households Using GPS-Enabled Cell Phones; Multimodal Monitoring with Integrated GPS, Diary and Prompted Recall Methods

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Project Title: "Measuring Travel Behavior of Low-Income Households Using GPS-Enabled Cell Phones; Multimodal Monitoring with Integrated GPS, Diary and Prompted Recall Methods"

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Overview of the research

The research demonstrated innovative methods for using GPS-enhanced travel and activity monitoring to measure, analyze, and verify highly resolved travel patterns of low-income households for multiple modes and days. Previous studies suggest the travel of low-income households varies significantly from more affluent households, but our understanding of how low-income residents navigate the urban landscape throughout the day is limited since they are less likely to respond to travel surveys and, when they participate, are more likely to underreport travel. The Harbor Communities Time Location Study (HCTLS) addressed these limitations through targeted sampling and the integration of traditional activity/travel diary methods with portable GPS monitoring and follow-up prompted recall interviews to verify patterns revealed in simultaneous diary-GPS monitoring. In early 2008 we monitored 10-14 days of travel of 51 residents of Wilmington and western Long Beach, port-adjacent low-income communities impacted by high levels of congestion and pollution due to goods movement activities. Results provide valuable insights for transportation planners and policy makers into the travel modes and patterns of low-income households and the rate at which they seem to underreport travel and activities on travel/activity diaries.

Research approach and tasks

9/07-12/07	Reviewed existing studies, Finalized study design, Obtained IRB Approval, Field tested and evaluated GPS devices
1/08	Pilot testing, Participant recruitment
2/08-6/08	Field study with rolling samples of 5-10 participants, Post-processing of GPS data for the generation of participant follow-up interviews
7/08-12/08	Post-processing of GPS data and analysis of travel and time-location patterns
1/09-6/09	Analysis and preparation of papers for publication

Methodologies

The HCTLS population was a nonrandom sample of 51 adult residents (21-65 years old) of the Wilmington area of the City of Los Angeles, California and the western portion of the City of Long Beach, California. We recruited participants through contacts with community health organizations, presentations at community meetings and adult education classes, informational tables at community events, fliers and advertisements in public spaces, and networking through word of mouth and through participants of previous studies.

Recruitment materials, training, and participation coordination were available in both English and Spanish given residents of the study area are predominately Hispanic and bilingual and monolingual Spanish speakers. Participants expressed concern about air pollution problems in their community and were highly motivated to help gather information that could support policy and planning solutions. Time-location data tracking was conducted between February and June 2008. Participants received grocery gift cards totaling $50 for their participation which included an in-home baseline survey and training, completion of time-activity logs for 3 days, 10-14 days of GPS location tracking, and an in-home follow-up interview.

During the initial in-home meeting we provided an overview of the study, gained informed consent, trained participants on completing the activity logs and operating the GPS devices, and conducted the baseline survey to gain demographic and SES information, household and building characteristics related to the potential intrusion of outdoor air pollution, household transportation resources, and general health status information. After the completion of participant activity tracking, we retrieved logs and GPS devices, generated map and tabular "prompts" regarding discrepancies, unclear patterns, and suspected unreported activities, and returned to participant homes to conduct follow-up interviews.

Due to software and battery life constraints identified in our field testing of GPS-enabled phones made available from the UCLA Center for Embedded Network Sensing (CENS), we decided to use portable GlobalSat DG-100 GPS devices, each of which provided sufficient memory and positional accuracy to meaningfully monitor participant locations for 7 days (participants used 2 devices to complete the required 10-14 days of GPS monitoring). These devices were relatively light-weight and were typically carried in a pocket or bag or clipped onto a belt, required nightly charging, and recorded the geographic coordinates of participant locations about every 15 seconds.

We examined GPS patterns using Geographic Information Systems (GIS) to overlay participant GPS coordinate locations over highly resolved and geographically rectified Digital Ortho Quarter Quads (DOQQ) aerial photography for July 2006 from the United States Geological Survey (USGS) in order to identify the time participants spent in major microenvironments (indoors, outdoors, and in-vehicle), traveling by mode (walking, biking, on transit, and in-vehicle), and major location type (home/residential, public building, service or retail locations, workplace, restaurant/bar, outdoors, and traveling/waiting outdoors or in an enclosed vehicle). We determined GPS point locations relative to building outlines and built environment features using DOQQ imagery, and we used GIS land use data, our knowledge of the study area, and the "satellite" and "street view" function of GoogleMaps (http://maps.google.com/) in order to confirm built environment configurations and to clarify location type/function. Participant notes and location information from logs helped further clarify details such as building location type (i.e., residence or retail location) or travel mode (i.e., traveling in a vehicle or on transit).

Key findings

Although we are continuing our analysis of the entire 10-14 days of GPS monitoring to examine variability in travel activities, we have completed analysis of the travel and time-location patterns for the 131 days on which 47 of the HCTLS participants adequately recorded their 24-hour location patterns using both self-reported time-activity logs and passive location tracking with a portable GPS device. During these "simultaneous" log-GPS activity tracking days, participants completed activity log each time they changed location or traveled and kept a portable GPS data logger with them during waking hours. We briefly describe below some of our results based on patterns on these "simultaneous" log-GPS activity tracking days.

Participants did not report about half of the location/travel identified in the GPS-enhanced data, an important insight given we are aware of only two studies in exposure assessment which assess the correspondence between activity log and GPS tracking. Phillips et al. 2001 (Phillips et al., 2001) identified short unreported trips on activity logs during 16 GPS trials with participants aged 21-55 years old in the Oklahoma Urban Air Toxics Study. Egulthun et al. 2007 (Elgethun et al., 2007) used GPS tracking to determine that parents of 31 children ages 3-5 years in Seattle, Washington misclassified time location patterns on diary timeline about 48% of the time, and that parents in Spanish-speaking households were more likely to misreport time-locations. Even though our methods and study population differed in significant ways, this rate is very similar to the underreporting rate among HCTLS participants (49%). Analysis of travel surveys from four California counties compared GPS vehicle tracking to travel diaries and suggested that respondents did not report 18-35% of vehicle trips (California Department of Transportation, 2002; Zmud & Wolf, 2003). In comparison, HCTLS did not report 44% of vehicle trips.

The HCTLS is first study to integrate participant-reported activity log and passive GPS tracking with follow-up interviews to document the time-location patterns of a low SES immigrant group in a major transportation and goods movement corridor. Participants were largely Hispanic women and homemakers and spent about 89% of their time indoors, about 5% of their time in enclosed vehicles, and about 6% of their time outdoors. Using these broad location categories, participant time-location patterns are were fairly consistent with those of adult respondents to previous random telephone recall surveys in California (Wiley et al., 1991), the United States (Klepeis et al., 2001), and Canada (Leech et al., 2002). Although many HCTLS participants were active volunteers and/or attended community education classes, they spent a significantly higher proportion of their time indoors at home than respondents to these previous surveys (78% vs. 63-66%). In this regards, HCTLS participants were most similar to unemployed adult respondents in the national NHAPS sample.

Innovations

The HCTLS is first study to integrate participant-reported activity log and passive GPS tracking with follow-up interviews to document the time-location patterns of a low SES immigrant group in a major transportation and goods movement corridor. Integrated methods were particularly beneficial in classifying time-location patterns of HCTLS participants because log completeness varied due to limited literacy skills and the frequency with which participants recorded activities. When available, activity log details provided valuable information about activity times, location types, microenvironment characteristics, and travel mode details which were not always readily apparent by overlaying GPS data with highly-resolved areal photography and land use maps. When not available, we prompted participants to provide these details in follow-up interviews and queried participants to clarify activities observed in GPS data which were not on logs (usually short trips or stops on a longer trip). Integrated activity tracking methods provide opportunities for clarification and cross-verification not available in telephone recall surveys and log-only activity and travel tracking.

Recommendations

We have demonstrated that emerging GPS technologies can be integrated with diary/log methods and prompted recall follow-up interviews to document the travel patterns of disadvantaged populations. As a pilot project, we have worked out many of the methodological issues, which would make the next step more feasible and cost effective. We analyzed GPS locations on the "simultaneous" log-GPS activity tracking days (described above) by manually reviewing all points using GIS overlays. Although this provided a high level of precision for identifying unreported activities and travel, this was a very time consuming aspect of our analysis. Future research should refine techniques to automate the classification of locations/travel through analysis of point patterns (distance, speed, etc) and roadway and building proximity. Automated classifications could then be verified as needed through GIS overlays.

Most GPS-based studies of travel behavior have focused on auto-travel, and future activity and travel studies should use and enhance the monitoring techniques we demonstrated to track multiple modes of travel, especially since transit, walking, and biking will likely be important part of expanding strategies to address urban environmental and health challenges. GPS-enhanced data could also provide insights into linkages between travel and location patterns and health outcomes. For instance, GPS-based analysis of shopping patterns could contribute to the growing literature on the spatial/transportation mismatch between disadvantaged populations and healthily food outlets. Our work demonstrates the feasibility of emerging technologies for tracking the patterns of disadvantaged populations, and more extensive monitoring is needed to document their patterns in order to improve travel models and to make transportation policy more effective for these communities.

The GPS-enhanced time-location data also provide a nearly continuous spatial database that can be used to model air pollution exposure on smaller time intervals based on proximity to pollution sources and concentrations over the course of the day, and improvement on previous modeling techniques which tend to use general activity data at fifteen or thirty minute intervals. GPS-enhanced time-location could also inform large-scale urban models of how the commute pattern relate to exposure to air pollution. For instance, how do exposures to ambient air pollution differ while at home, work, or while traveling?

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